GEOPHYSICAL INSTITUTE

University of Alaska

Fairbanks, Alaska 99701

COORDINATED OBSERVATIONS OF CHEMICAL RELEASES

FROM THE GROUND AND FROM AIRCRAFT AT HIGH LATITUDES

Final Report

Grant NGR 02-001-094

Oct. 1, 1972 - June 30, 1973

Prepared for

National Aeronautics and Space Administration

Headquarters, Washington, D. C. 20546

Principal Investigator   Report Approved By:

Gerald J. Romick (signature)   _K. B. Mather_ (signature)

Gerald J. Romick ·   Keith B. Mather
                           Director
                           Geophysical Institute

ABSTRACT

On October 13, 1972, at 15:11 U.T. a sodium-lithium (Na-Li)
trail was released from a Nike-Apache rocket launced from the
Poker Flat Rocket range in Alaska. Ground based photographic
equipment at Ester Dome, Alaska, recorded the development of
the trail for approximately twenty minutes. Photographic coverage
of this event was also obtained on the NASA Convair 990 and is
the subject of analysis by the Geophysics Corporation of America.
Only the ground observations obtained by the Geophysical Institute
are discussed in this report. Although haze and the twilight
background in the photographs prohibited the detection of stars
which is necessary for accurate angular determination of the
position of the trail, some reduction of the data has been possible.
By using the nominal trajectory for a 60 pound payload and the
particular rocket, a best fit trajectory was determined based
on the Ester Dome photographic data, launch time and earth-sun
geometrical shadow height. From these calculations, the height
of obvious features along the trail were determined and their
velocity estimated. A clockwise rotation of the velocity
vector with increasing height was observed. Velocities deduced
at various altitudes were then compared to meteor radar data also
obtained during this period. The comparisons of these two neutral
wind measurements techniques are satisfactory if the meteor deduced
wind orginated in the 90 to 94 km region which is not unreasonable.
Due to the unknown errors involved in these data because of the angular
accuracy available, we feel that further detailed analysis is

not warranted unless it is necessary to the interpretation

of the analysis of the aircraft data.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

In recognition of the need to study the dynamics of the neutral atmosphere at all latitudes and times of the day, a NASA sponsored series of rocket trail releases was scheduled for the period October 8-15, 1972, from the Poker Flat Rocket Range in Alaska.

The initial program was for three trail releases: one of trimethyl aluminum (TMA) and two of a combined Sodium Lithium (Na-Li) payload between 90 km and 160 km. The initial plan was to have multistation ground observations operated by the Geophysical Institute in cooperation with airborne observations on board the NASA Convair 990 directed by the Geophysics Corporation of America (GCA). The TMA trail was to be released in evening twilight. One Na-Li payload was scheduled for release in the morning twilight at a solar depression angle near $10°$ with the other near $2°$ to enable the aircraft to initially be in the shadow. This would allow observations to continue until sun rise above the aircraft horizon or, essentially, until conditions approximated a day-time release.

The main purposes for this program were 1) to determine the effects of geomagnetic activity on neutral atmosphere dymanics, 2) to find and compare the errors from ground-based and aircraft-based triangulation techniques in determining neutral wind profiles, and 3) to develop in general, the observational techniques needed to deduce wind profiles from chemical trail releases during the daytime from aircraft or space platforms.

Because of financial limitations and the lack of clear weather, modifications were made in the original concept of the experiment. The ground-based observations made by the Geophysical Institute were de-emphasized and only photographic observations using the 35mm All Sky Camera, the narrow field 35mm camera and the 16mm color camera were made from the Ester Dome Observatory. In addition, meteor radar wind observations were made near Fairbanks, Alaska. Incoherent scatter radar data were taken at the Chatanika radar site by Stanford Research Institute, and 70mm image inten-sifier photographs were made by a NASA-Wallops group at Ester Dome. GCA, under Dr. J. Bedinger, carried out the rocket payload and assembly details as well as the camera operation on board the NASA Convair 990 jet aircraft. The purpose of this report is to illustrate the ground-based data which was obtained by the Geophysical Institute and present a preliminary reduction of some of the data. Obviously, on the funds which were provided to the Geophysical Institute for this task, little detailed reduction can be done and no detailed analysis of the data to satisfy the specific intent of the original proposal has been attempted. On the basis of the available data, it is not anticipated that further use of the ground data will be necessary. The analysis of the airborne data being done separately by Dr. J. Bedinger at GCA is of excellent quality.

GROUND BASED OPERATION AND DATA ACQUIRED

The three rockets of this program were designated NASA rockets 14.506 CA/TM-6119 (TMA), 14.504 CA/TM-6117 (Na-Li), and 14.505 CA/TM-6118, or Poker Range numbers PFNA-43, 44, 45 respectively.

Due to a malfunction of the second stage igniter, PFNA-43 failed to produce a TMA trail at local evening twilight on U.T. October 13, 1972. Both PFNA-44 and 45 were launched successfully in the local morning twilight of U.T. October 13, 1972. Due to overcast sky conditions no usable data was obtained at Ft. Yukon, Alaska. Although a thin overcast was also present at Ester Dome, Alaska, the Na-Li trail from PFNA-44 was clearly seen for at least 20 minutes; however, because of the overcast, no stars were obtained on any of the photographic data. No ground-based optical data was obtained during PFNA-45 as the combination of thin overcast and small solar depression angle completely overexposed the film in the exposure time needed to detect the trail. Thus the only ground-based data obtained was that from the 35mm ASC at Ester Dome, the narrow field (35mm) camera, and the 16mm color movie camera for the Na-Li trail released at 15:11 U.T. October 13, 1972 from PFNA-44.

Figure 1 is a composite of 10 ASC prints between 15:12:45, (the first recorded appearance of the trail was at 15:12:12), until 15:31 after which the rising sun begins to mask the cloud. The rocket continued to emit a trail until it re-entered the earth's shadow on the down leg at 15:17:30. Figure 2 is a composite tracing of the cloud outline superimposed on an elevation azimuth grid for the All Sky Camera on each of the All Sky Camera photographs shown in Figure 1.

Figure 3 is a series of black and white prints, made from the 16mm color film, of the initial development of the trail as seen from Ester Dome. The approximate angles are indicated on the right side, and points used in the velocity determination are

3

ESTER DOME   OCTOBER 13, 1972

Figure 1a.   All Sky Camera Photographs from Ester Dome, Alaska
showing the temporal development of the Na-Li trail
released at 15:11 U.T., October 13, 1972.

ESTER DOME OCTOBER 13, 1972

UT 15:20:50

UT 15:22:50

UT 15:24:50

UT 15:26:53
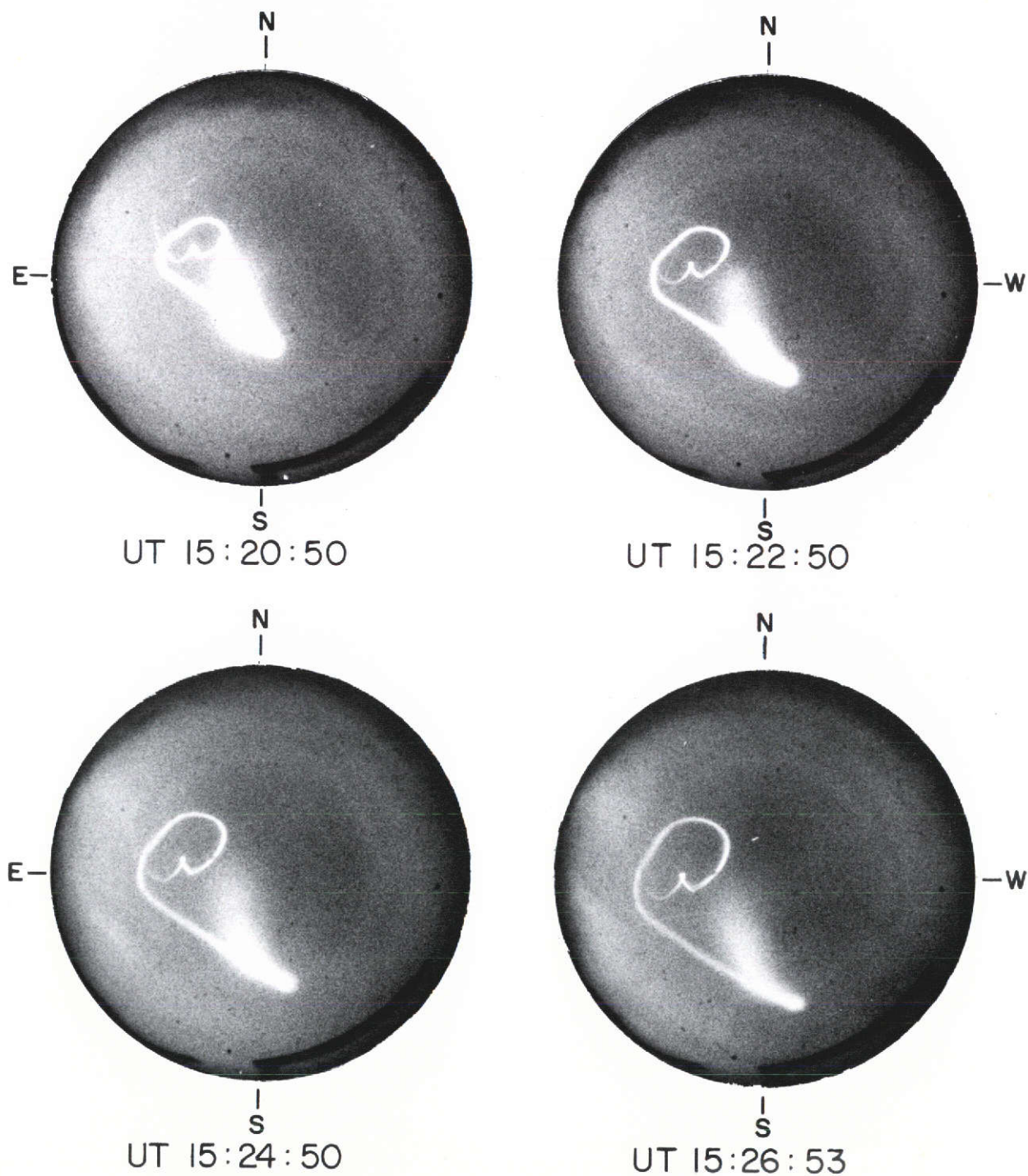
Figure 1b. All Sky Camera Photographs from Ester Dome, Alaska
showing the temporal development of the Na-Li trail
released at 15:11 U.T., October 13, 1972.

ESTER DOME   OCTOBER 13, 1972
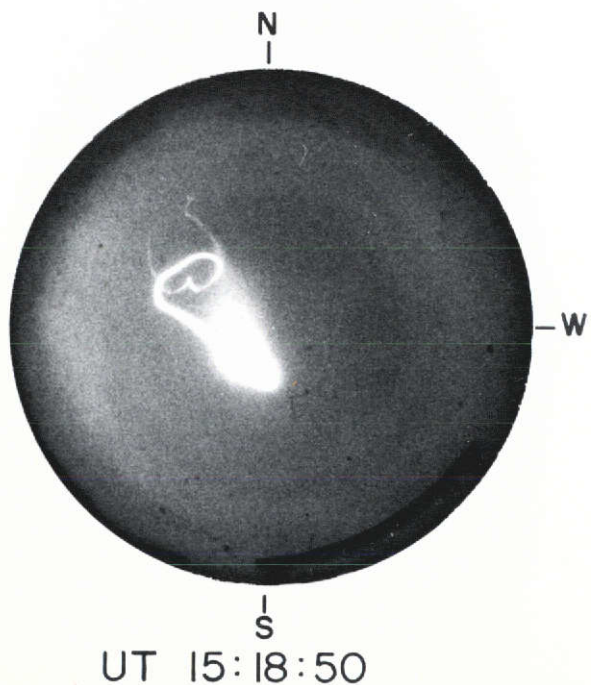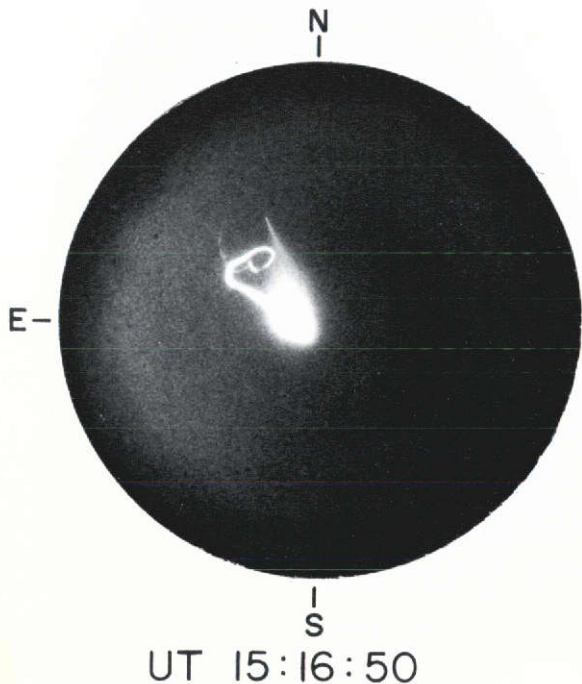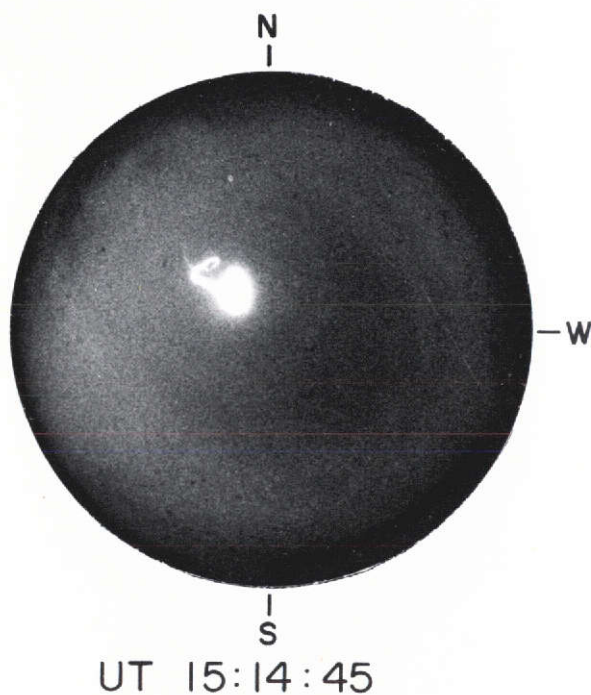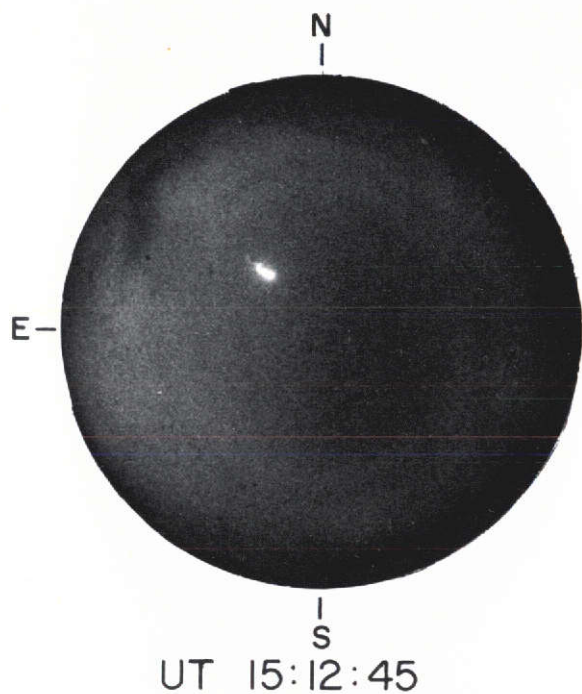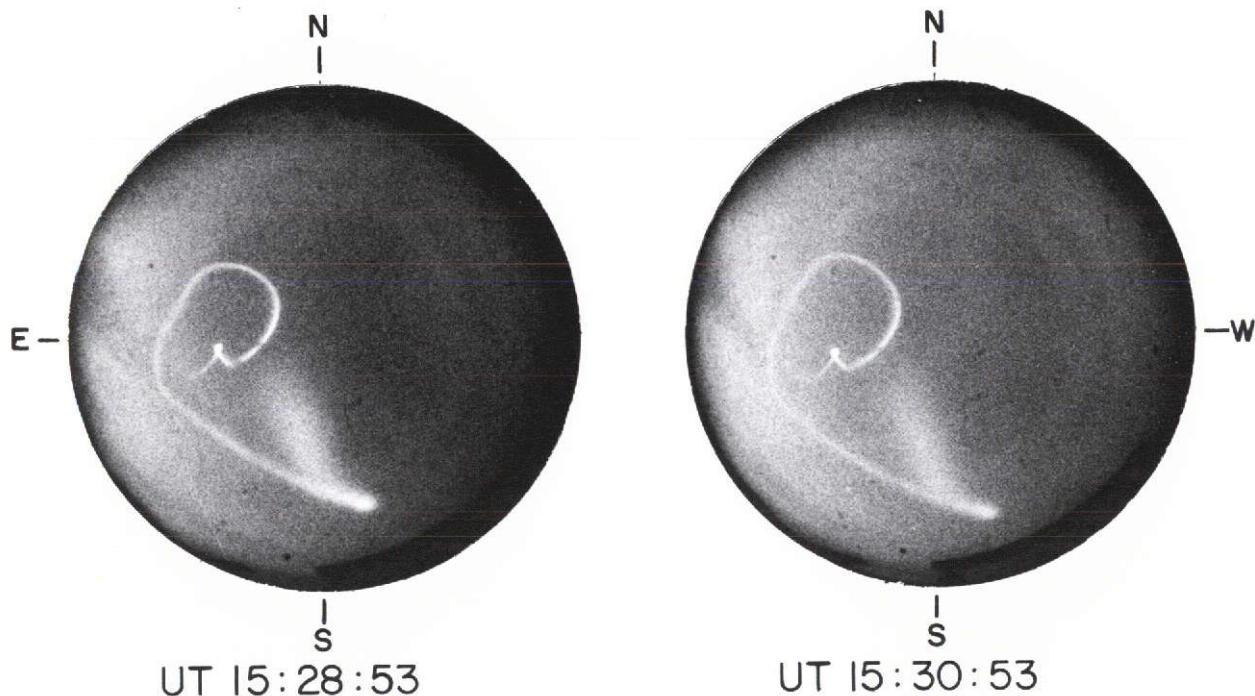

Figure 1c. All Sky Camera Photographs from Ester Dome, Alaska
showing the temporal development of the Na-Li trail
released at 15:11 U.T., October 13, 1972.

ESTER DOME   OCTOBER 13, 1972

UT 15:12:45

UT 15:14:45

UT 15:16:50

UT 15:18:50

Figure 2 a   Tracings of the all sky camera Na-Li
trail observations from Figure I super-
imposed on an elevation azimuth grid for
the all sky camera. The points labeled
A,B,C are used for the velocity-calcula-
tions. Circles are in 5° increments.

7

ESTER DOME OCTOBER 13, 1972

UT 15:20:50

UT 15:22:50

UT 15:24:50

UT 15:26:53

Figure 2 b   Tracings of the all sky camera Na-Li
trail observations from Figure I super-
imposed on an elevation azimuth grid for
the all sky camera. The points labeled
A,B,C are used for the velocity calcula-
tions. Circles are in 5° increments.

8

ESTER DOME   OCTOBER 13, 1972

UT 15:28:53

UT 15:30:53

Figure 2   c   Tracings of the all sky camera Na-Li
trail observations from Figure 1 super-
imposed on an elevation azimuth grid for
the all sky camera. The points labeled
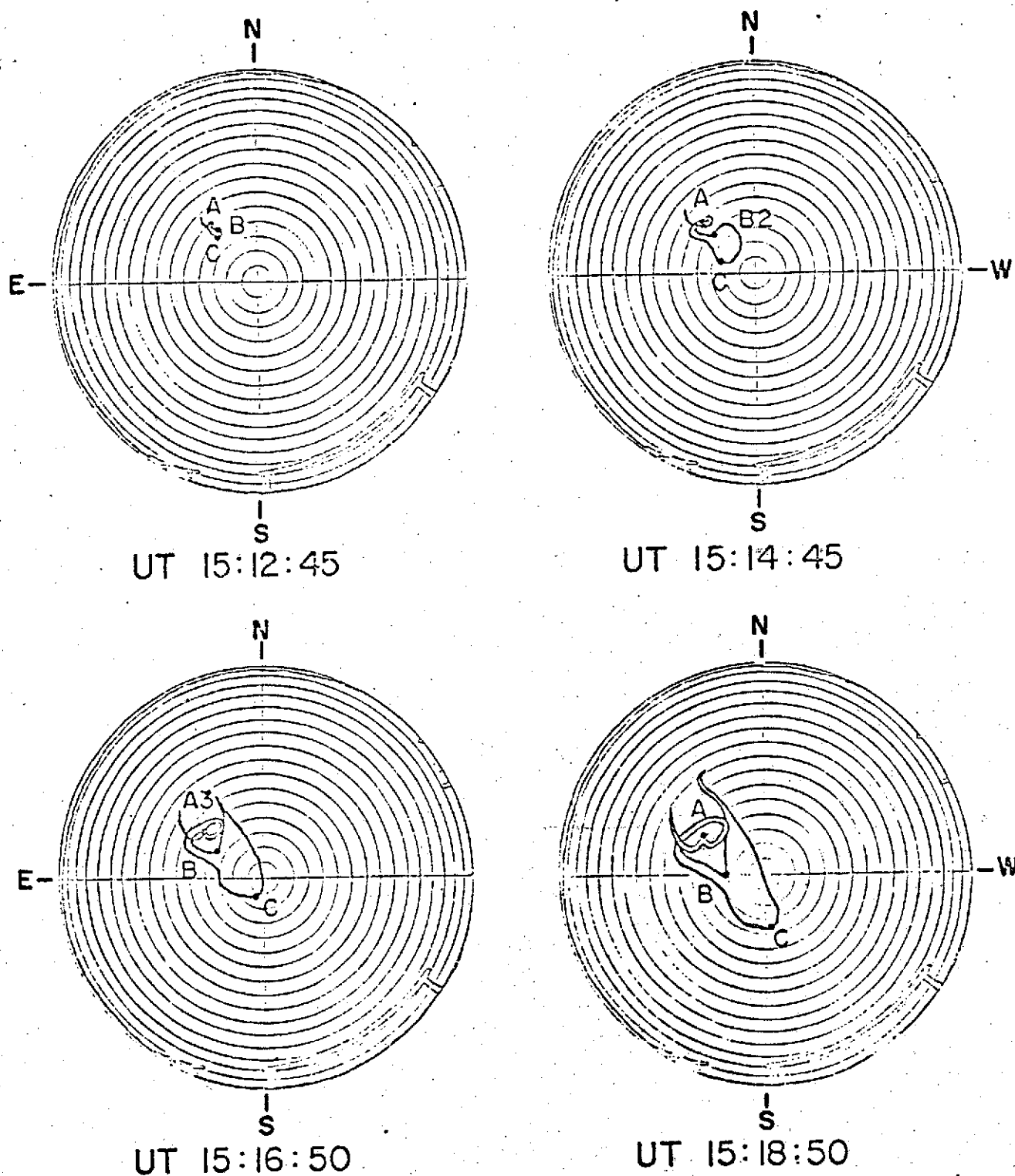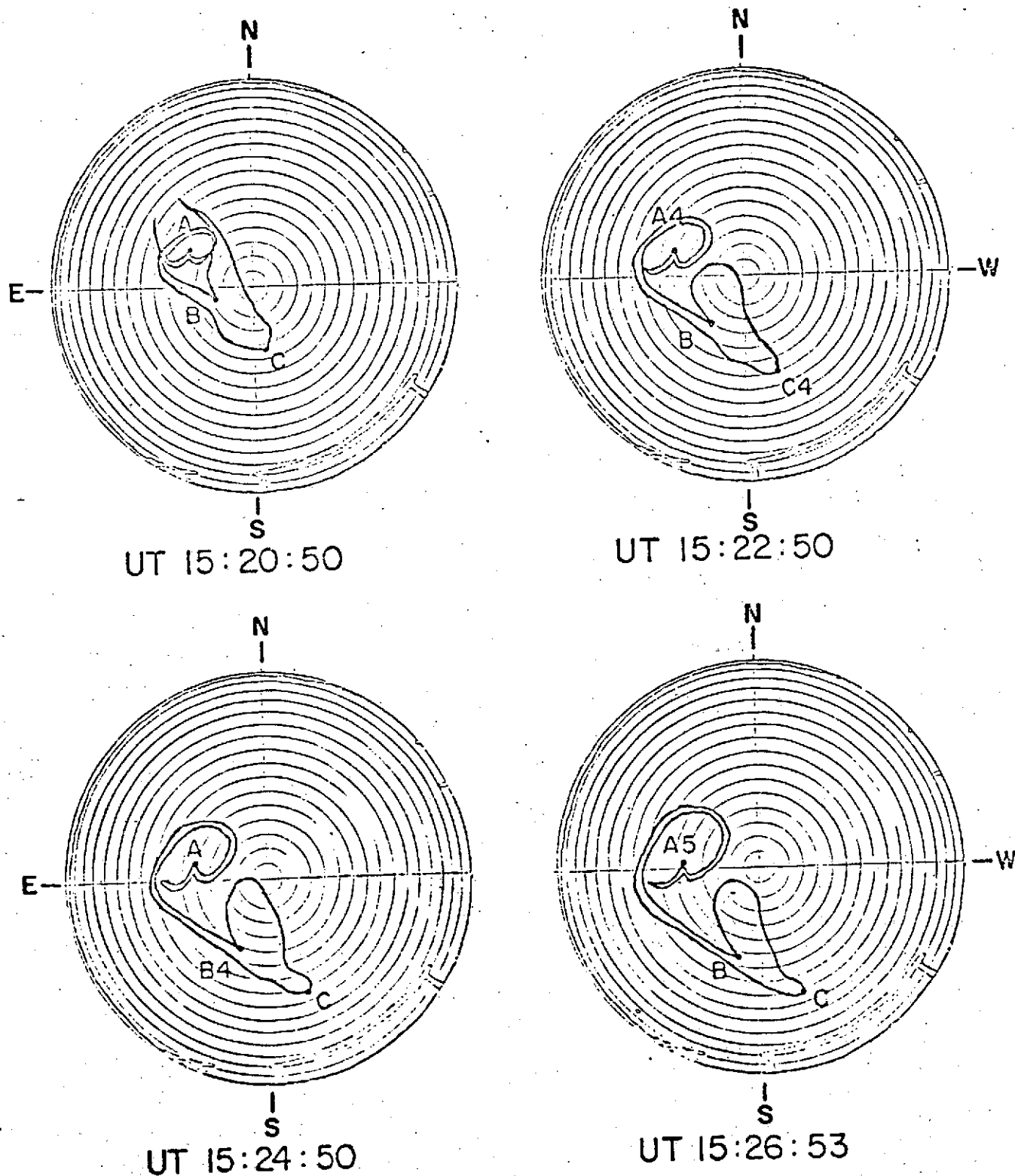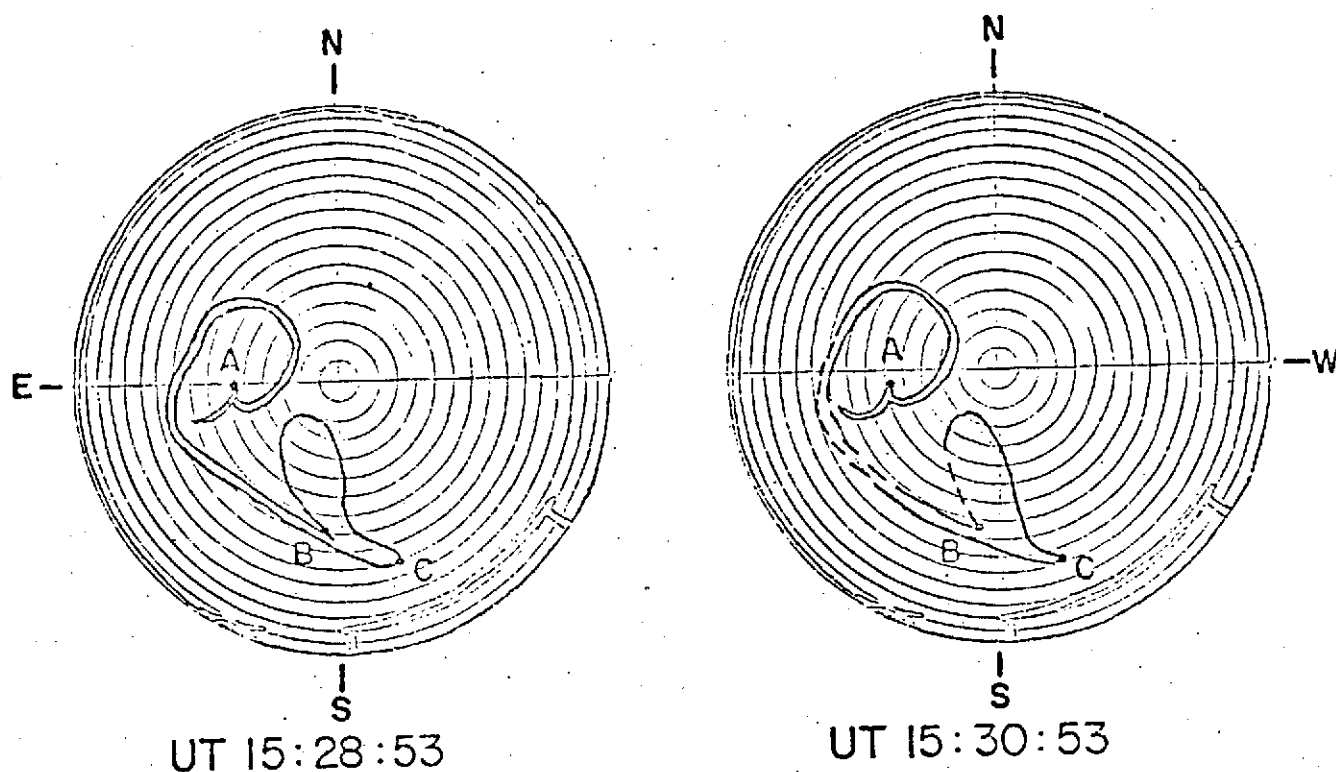A,B,C are used for the velocity calcula-
tions. Circles are in 5° increments.

Indicated as A, B and C. Figure 4 shows the magnetometer records at College, Poker Flat and Ft. Yukon for U.T. October 13, 1972.

ROCKET TRAJECTORY

In order to determine the approximate velocities and height range of the Na-Li trail to correlate with the meteor radar data, an attempt was made to determine the trajectory of the rocket and initial height distribution of the trail.

Using many diagrams of the type illustrated in Figure 2 from the ASC data, the elevation and azimuth of the rocket on the ascent and descent were deduced as a function of time as seen from Ester Dome. These data are plotted in Figure 5 along with the trajectory expected for a typical 60 pound payload Nike-Apache rocket launched from Poker Flat on an 18° azimuth with a Q.E. of 88°. These launch conditions are the values which best fit the observations from Ester Dome and only differ slightly from the initial settings of the launcher which were 20° azimuth and 86° elevation angle. The constraints imposed by the Ester Dome observations from both the ASC and narrow field cameras, the nominal trajectory, constant horizontal velocity of the rocket after 60 seconds, and the height of the rocket at the time of exiting and reentering the earth's geometrical shadow require the launch angles previously indicated. The fit is adequate as seen in Figure 5.

Figure 6 illustrates the best fit trajectory as seen along the launch azimuth from the launch site and shows the height of the rocket as a function of both the horizontal range and time.

LITHIUM TRAIL : ESTER DOME
OCTOBER 13, 1972 UT
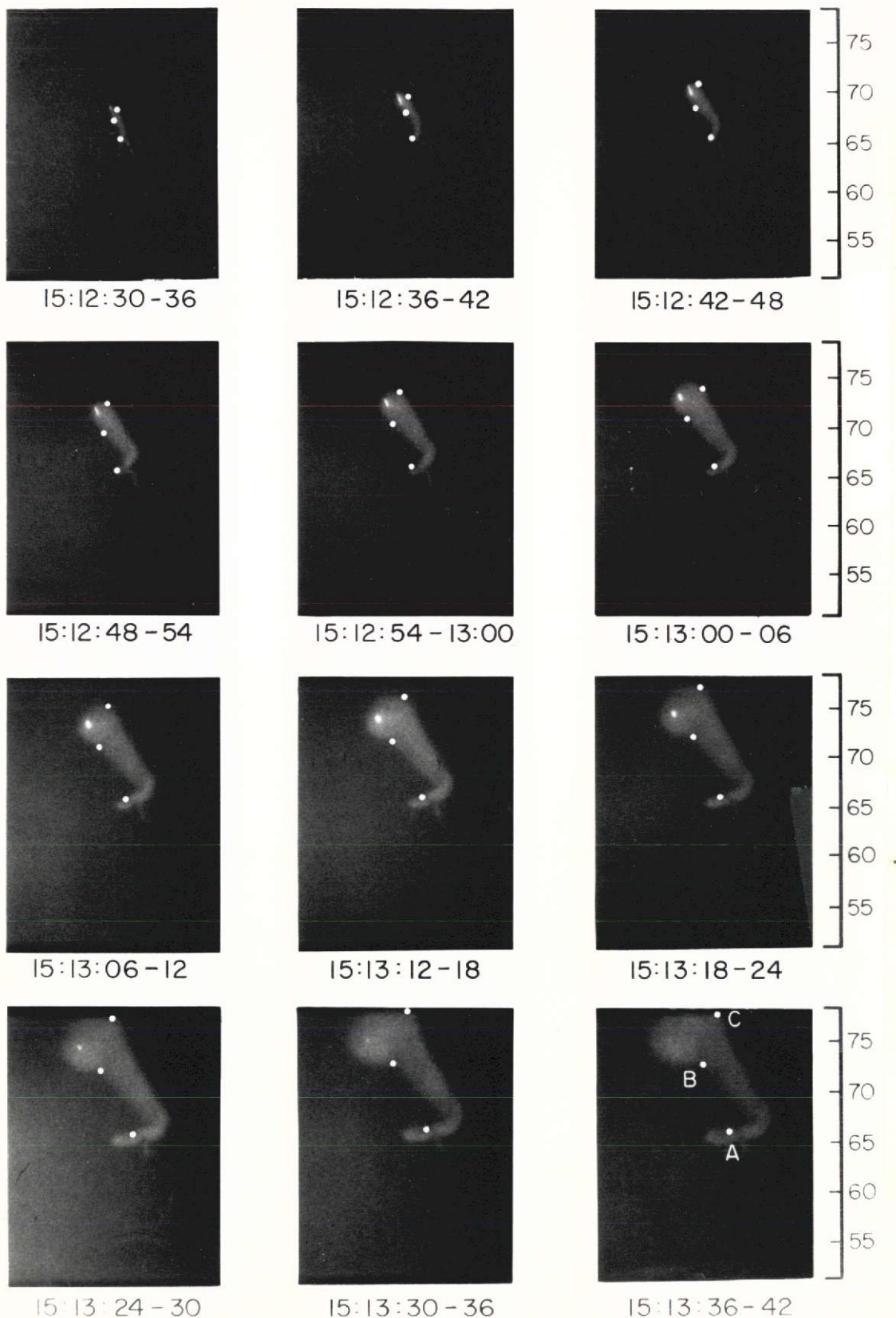
Figure 3. The temporal development of the Na-Li trail as seen from Ester Dome, Alaska using 16mm color film. The points labeled A,B,C are those used in the velocity calculation.
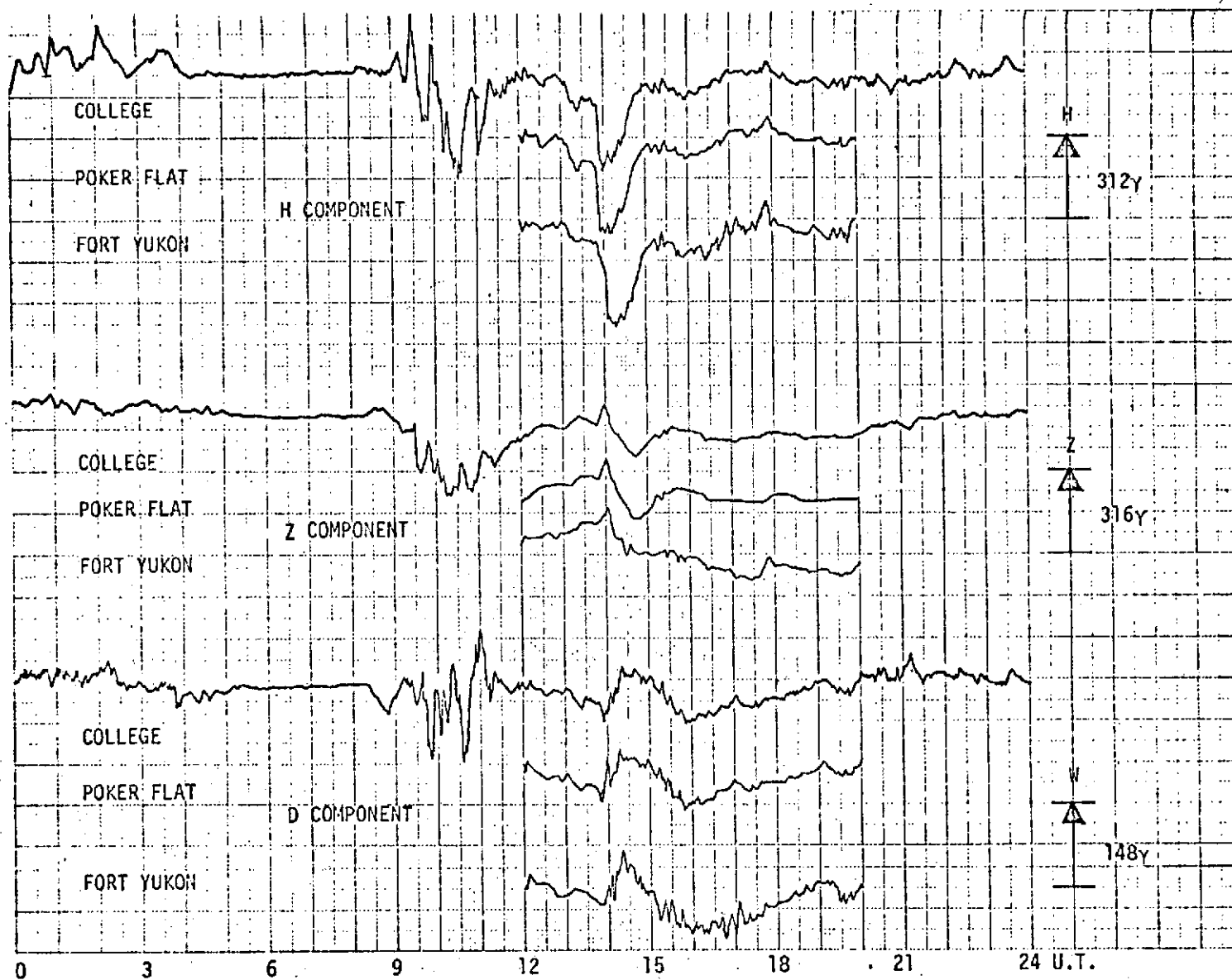
Figure 4   Magnetometer records for U.T. October 13, 1972, from College, Poker Flat and Fort Yukon.
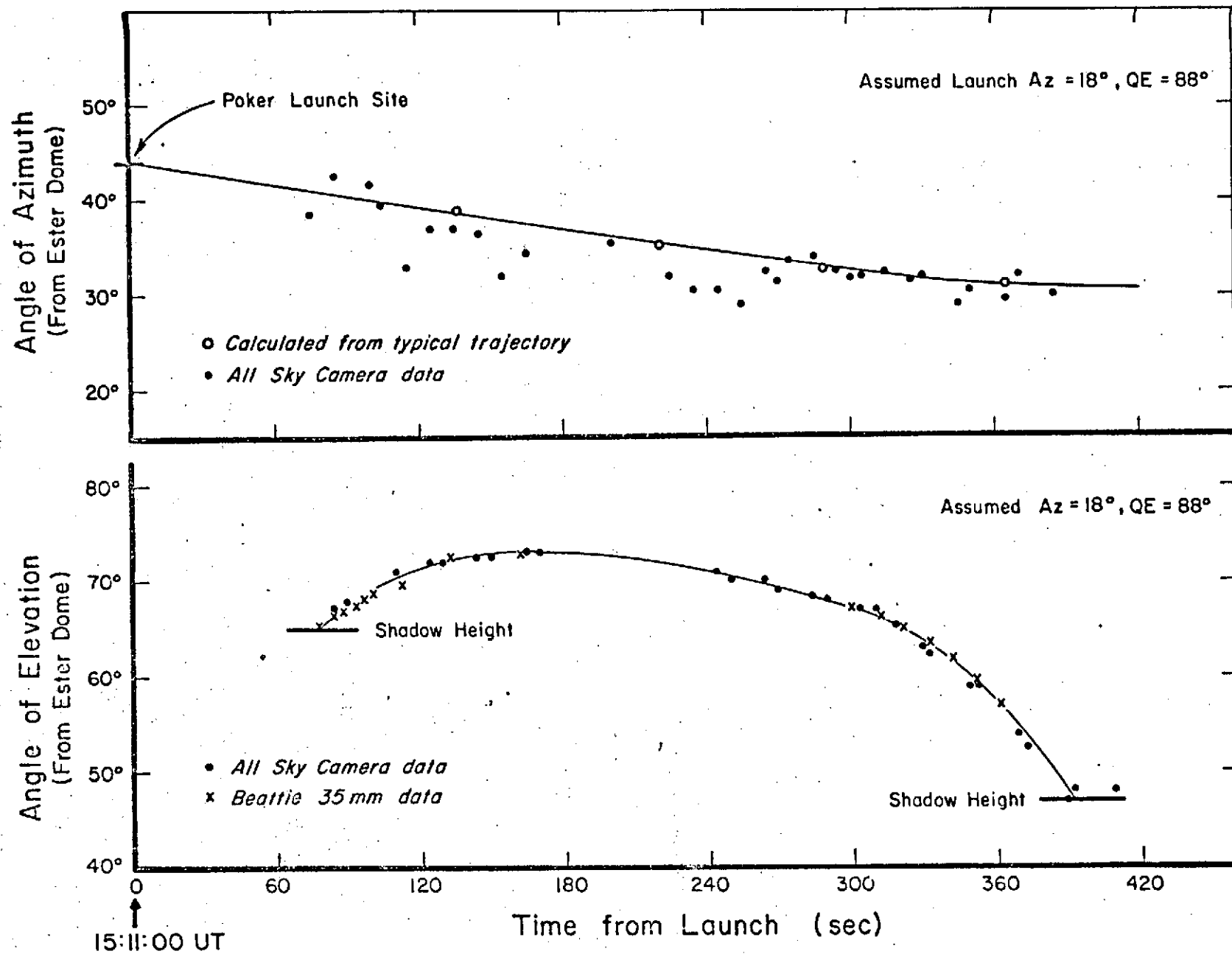
Figure 5   The rocket trajectory in terms of elevation and azimuth versus time as seen from Ester Dome compared to calculations from a typical rocket trajectory.

13 OCTOBER 1972 UT
(Calculated from ASC and typical trajectory)
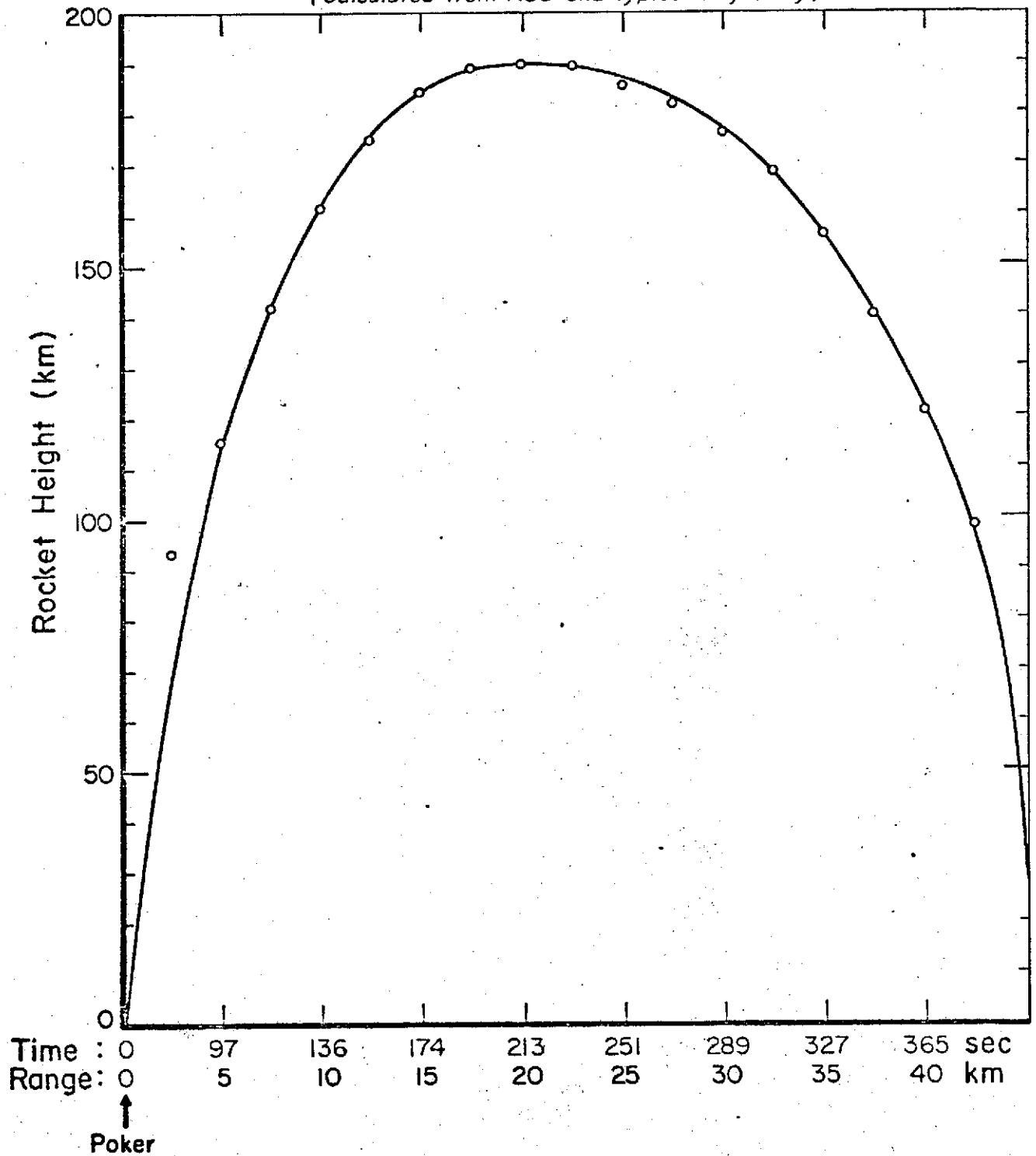
Figure 6   The rocket trajectory in height and range from the launch site as calculated using the Ester Dome all sky camera data and typical rocket trajectory data.

DEDUCTION OF NEUTRAL VELOCITY

To get some idea of the velocities of the neutral winds at
the low altitude regions appropriate for comparison with the meteor
wind data we attempted to use the ASC data to follow some obvious
features of the trail. The altitude of a particular feature was
obtained from the position of the rocket during the first few seconds
after release, that is, after a particular feature had developed, but
before the trail expanded or moaved far from the initial release
region. We recoginzed that this is not an accurate procedure but
should result in reasonable values relative to each other at the
different altitudes selected. The elevations and azimuths of
these features were obtained as a function of time and, by assuming
flat earth geometry, the azimuth and distance between the initial
release and that at the same altitude at any later time was determined.
The results of the calculation of the average velocity and direction
of motion are shown in Figure 7 for three distinct features which
occurred initially at 94 km, 98.5 km, and 118 km. These features
are indicated on the photographs and drawings in Figures 1, 2, and 3
and are labeled A, B, and C respectively. The numbers on the points
shown in Figure 2 are those used for the velocity calculations of
Figure 7.

METEOR RADAR OBSERVATIONS

The meteor radar at College is a continuous wave Doppler system

operating at 30.2 MHz with a transmitter power output of about 1 kw

15
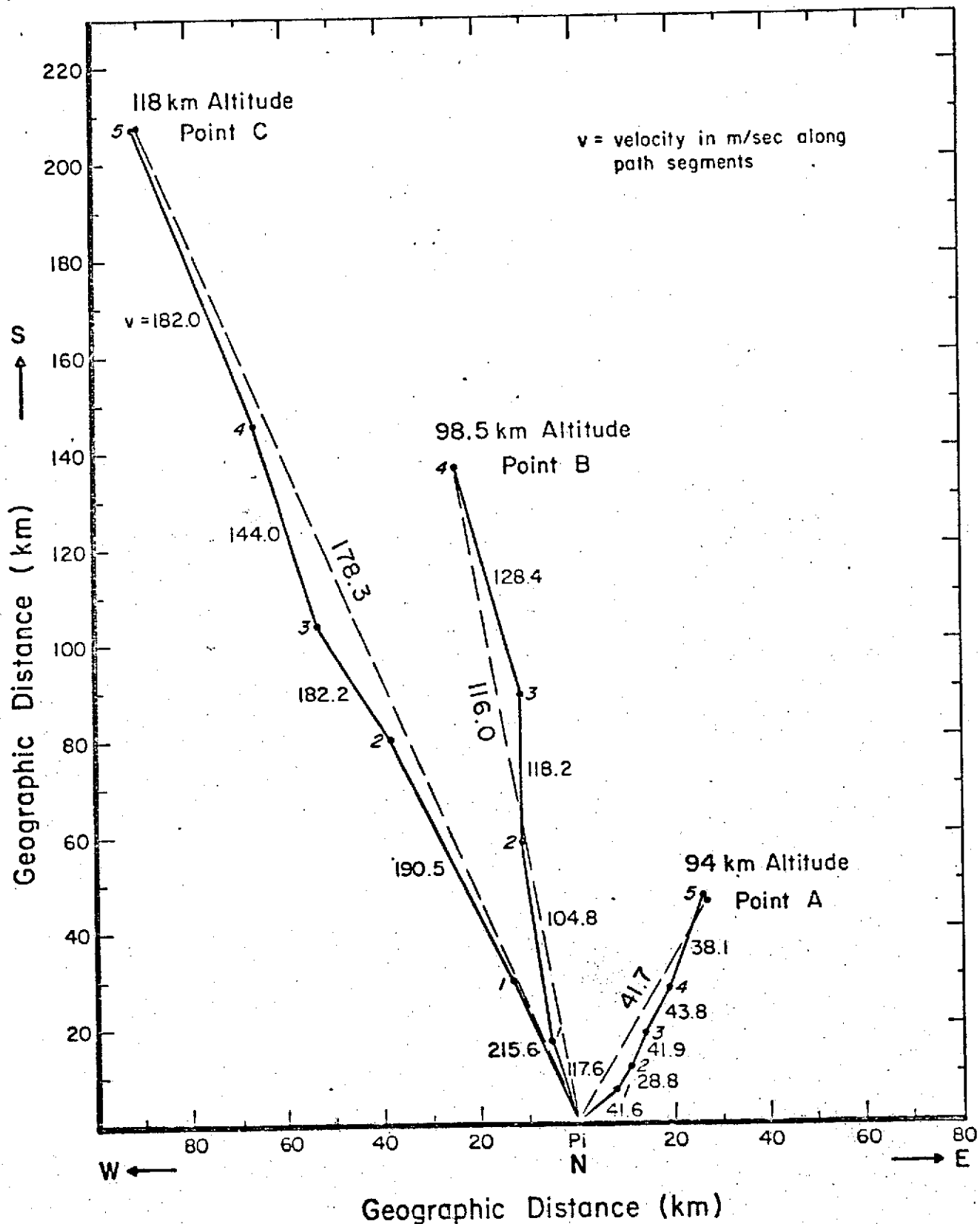
Figure 7   Vector components for the neutral wind velocity at three different heights along the Na-Li trail.

TABLE I

Numbers of Meteors Measured with Particular Directions and Speeds

Direc-tion	Time UT	Toward West or North Speed Range m/s										Toward East or South Speed Range m/s									
		91 100	81 90	71 80	61 70	51 60	41 50	31 40	21 30	11 20	01 10	01 10	11 20	21 30	31 40	41 50	51 60	61 70	71 80	81 90	91 100
N-S	1500-1605	0	0	0	1	1	0	2	1	0	0	0	1	2	1	3	3	1	1	1	0
E-W	1500-1605	0	0	0	0	0	0	0	2	0	0	0	0	1	1	4	5	2	3	0	0
N-S	1500-1530	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	1	0	0	0	0
E-W	1500-1530	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0
N-S	1530-1605	0	0	0	1	0	0	1	1	0	0	0	1	1	1	2	2	1	1	1	0
E-W	1530-1605	0	0	0	0	0	0	0	2	0	0	0	0	1	1	3	4	1	3	0	0

In two sidebands that are 500 Hz apart. The radar signal is directed northwest through a widebeam (>90°) antenna. From radar signals reflected from individual ionized meteor trails, the Doppler shift and sense (approaching and receding target), and the range of the point of reflection on the meteor trail are measured. The radar receivers are located 10 km east of the transmitter site. Two narrow beam (⊂ 30°) antennas at the receiver site are directed one to the west and one to the north. Thus both the east-west and the north-south component of the wind are derived from meteors within the beam of the respective antenna. The east-west winds are obtained from meteor trails located about 50 to 350 km west of College and the north-south winds are obtained from meteor trails located similar distances toward the north. The height of the reflection point was not measured and, therefore, the wind components obtained are an average through the meteor region. Most meteor particles evaporate in the 80 to 100 km height interval and thus the winds obtained represent some kind of average velocity in this height region.

The magnitude and direction of the drift of meteor trails observed between 1500 and 1605 U.T. is shown in Table 1. The data shown indicate that there is a consistent wind toward the east. Out of a total of 18 meteors observed by the west antenna over the interval of one hour, 14 meteors show eastward motions between 41 and 80 m/s. Only two meteors showed a westward motion. The north-south flow appears to be a little more variable than in the east-west direction. As shown in Table 1, 13 meteors drifted southward and 5 meteors drifted northward. Thus within the meteor height range (80-100 km), the wind appears to be mainly toward the south with a

18

velocity of 41 to 60 m/s at some height interval and at some other height interval the wind is toward the north roughly in the range of 20-70 m/s.

COMPARISON OF THE METEOR RADAR DATA AND THE TRAIL DATA

Table II lists the heights and neutral velocity components obtained from the trail analysis shown in Figure 7 and from the meteor radar analysis discussed in the previous section.

Table II

Height, Direction and Magnitude of the Neutral Wind

Height (km)	Meridional Component (+N) m/s	Zonal Component (+W) m/s
94	– 36	–21
98.5	–114	+20.8
118	–163	+71.8
Radar	– 50 $\pm$10	–60 $\pm$20

The accuracy of the radar data is the deviation of the measured components about the average velocity. It is difficult to estimate the actual error in the meteor radar, but it is probably less than 10 m/s (Hook, 1972). The error in the trail data is more one of height than actual velocity since the gradient in the velocity shear is so high in the lower altitude region that a small change in height may seriously affect the velocity measurements.

DISCUSSION AND CONCLUSIONS

The meteor radar calculated wind components and those deduced from the trail exhibit similar trends. As pointed out in the previous section, the radar wind components are derived from meteor trails located 150-350 km north and west of the Na-Li trail. Over these horizontal distances, the wind pattern is expected to be similar but small scale variations in the wind probably exist (Hines, 1960 and

19

Hook, 1970). If this separation between the radar observations and Na-Li trail is neglected, it would appear that the effective height of the meteor echoes is a little below 94 km, that is, the meteor derived winds more closely match the motion of the Na-Li trail in the 90-94 km height range. This is certainly in the expected 80-100 km height range for meteor radar echoes. The trail also appears to have a clockwise rotation of increasing velocity with height as is usually observed in mid-latitudes, (Rosenberg, 1968). The shear in the velocity with height is also similar to that observed in some trail releases at Ft. Churchill. An analysis of some of the Ft. Churchill releases has been done as part of the Ph.D. thesis of D. D. Wallis. The thesis is on the influence of magnetic activity on the motion of the neutral atmosphere. The section pertinent to trail releases is included as Appendix A. In general, magnetic activity has little effect on the atmosphere below 120 km whereas a sizable influence exists on the zonal flow due to ion drag acting as a driving source on the neutrals at higher altitudes. It is conceivable that joule heating and other effects may introduce some auxiliary influence at the lower altitudes after periods of prolonged electric field perturbation of the ions. However, the region below 120 km is complex and no obvious relation between the observed velocities and magnetic activity has been found.

This particular trail release was useful in helping to establish the capabilities of the aircraft for observing the trail during the day as well as during twilight periods. We assume additional data will be forthcoming on the analysis of the aircraft data through GCA. Although no accurate position data was

obtained because of the sky haze condition, there was sufficient information to show that the meteor radar data must have originated from events predominantly below the 94 km region and that a large height dependent velocity shear existed during this disturbed period. Further analysis of the ground-based observations alone appears unwarranted. Additional effort may be needed if the data are necessary to the analysis of the aircraft data.

ACKNOWLEDGEMENTS

REFERENCES

Hines, C., Internal gravity waves at ionospheric heights,
Can. J. Phys., 1441-1481, 1960.

Hook, J. L., Winds at the 70-100 km Level at College, Alaska,
Planet. Space Sci., 1623-1638, 1970.

Hook, J. L., The College Meteor Radar, University of Alaska Geo-
physical Report R 223, June 1972.

Rosenberg, N. W. Dynamic Model of Ionsopheric Wind Profiles,
Jour. Geophy. Res. 73, 4965, 1968.

Wallis, D. D., Ph.D. Thesis in preparation, 1973.

Appendix A

Section of Chapter 4 – Ph.D. dissertation in preparation

D. D. Wallis

4.5 Trail Release Wind Observations at Fort Churchill, Canada

Figures 4.20 and 4.26 include all the published wind profiles made at Fort Churchill, Canada, by the vapor trail technique (Bedinger, 1966, 1971). Two characteristics of these profiles are immediately apparent, a) the presence of large oscillations in speed and direction which are especially marked below 110 km and, 2) in the first half of the examples, a nearly linear speed increase with altitude between 120 and 160 km in a westerly direction. Although there is no definite proof that the oscillations are due to internal atmospheric gravity waves, Kockanski (1966) has made just this identification for the three, May 1963, profiles shown as figures 4.21 and 4.23. An important characteristic of these oscillations is the tendency for extrema in speed to occur at the same altitudes as marked changes in vector direction. These oscillations are commonly observed between 80 and 110 km in low-and-middle latitude wind profiles. When the amplitude and vertical wavelength are plotted as a function of height, the result is very similar to that expected for internal gravity waves (Kockanski, 1966).

On occasions similar oscillations are present above 120 km. Kockanski (1966) has identified their presence up to 180 km. This may be the cause of the irregularities appearing above 120 km in the present data. Examples appear at 130 km in figure 4.22 and at 140 km in figure 4.23. These observations are made to support the contention that wavelike disturbances appear in the data. However, primary emphasis is to be placed on larger scale (vertical) phenomena. The presence of these oscillations has no real consequence in the argument which is to follow because of their relative small magnitude.
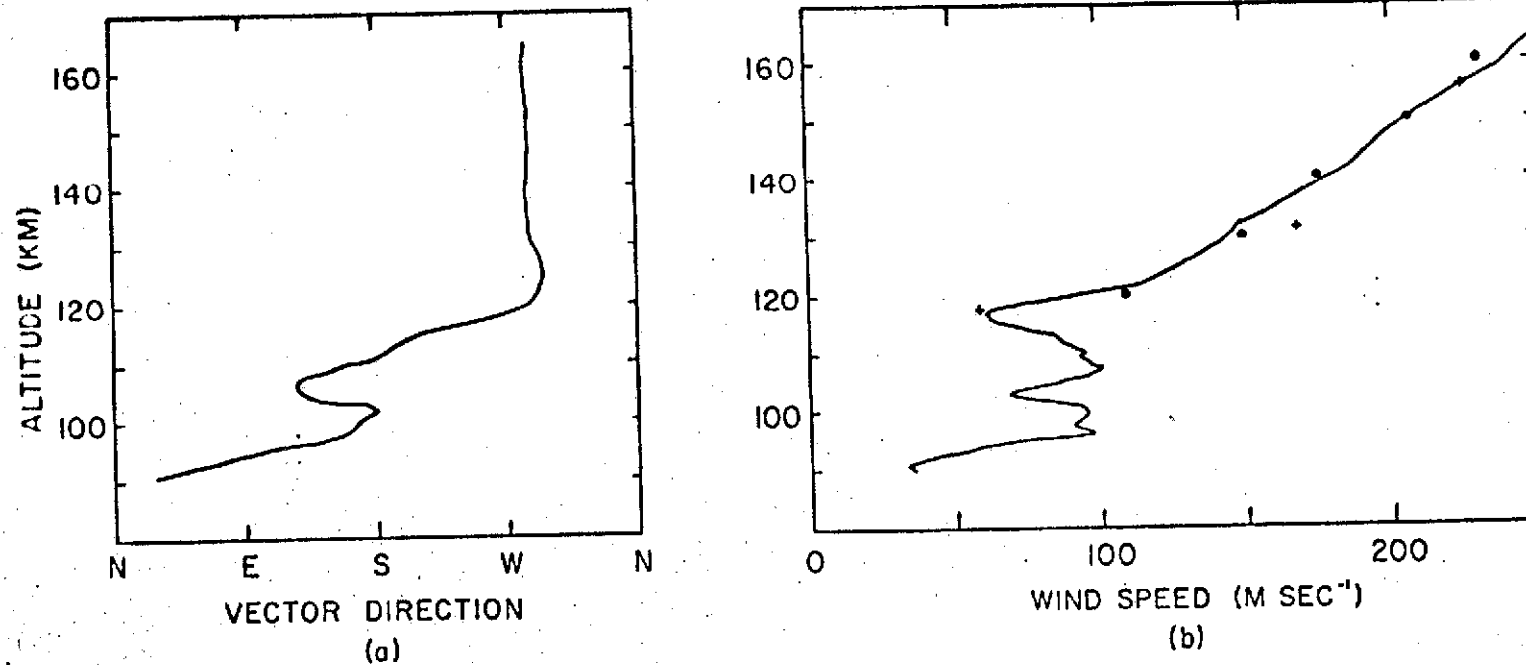
1

15 SEP 1966

1922 CST

Figure 4.20 Vector neutral wind profile observed above Fort Churchill, Canada
from a TMA release at 1922 CST. 15 September 1966, showing (a) the geographic
direction of motion as a function of altitude, and (b) the wind speed as a
function of altitude. Crosses (+) are theoretical speeds computed by Fedder
and Banks (1972) normalized at 155 km. Dots are theoretical speeds from Heaps
(1972) normalized at 150 km.
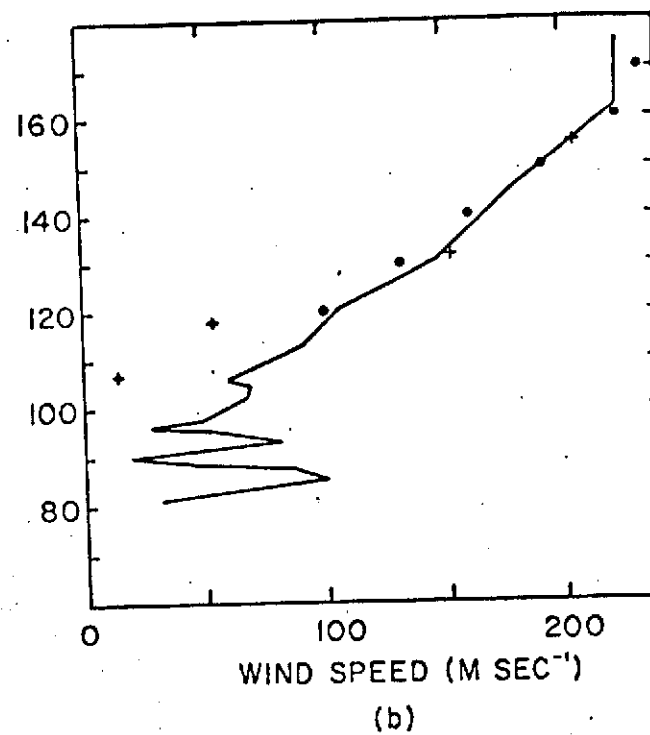
21 MAY 1963
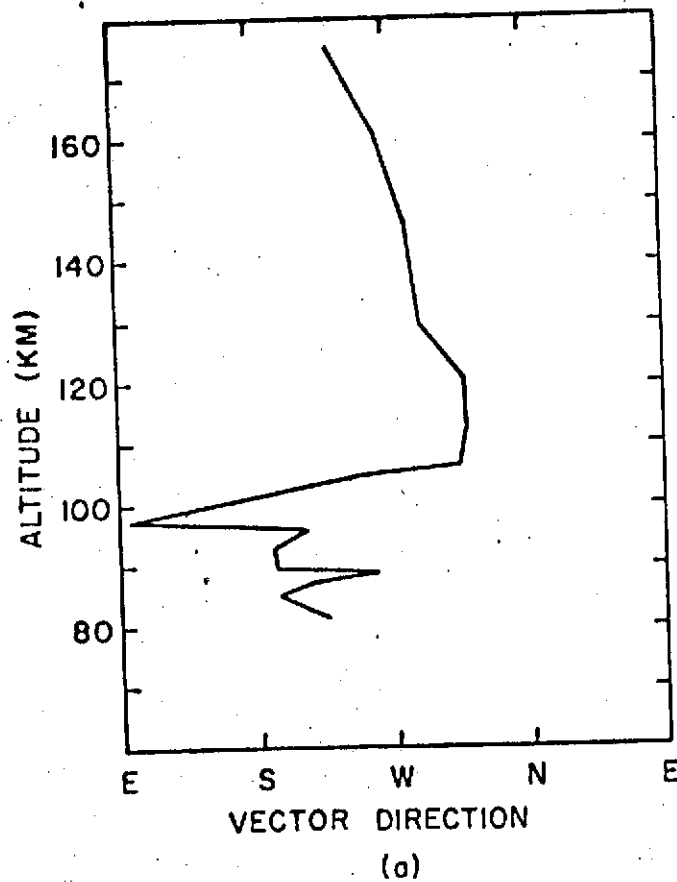## 2200 CST

(a)

(b)

Figure 4.21 Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 2200 CST. 21 May 1963. Refer to figure for other details.

22 MAY 1963
0131 CST

(a)

(b)

Figure 4.22 Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 0131 CST. 22 May 1963. Refer to figure   for other details.

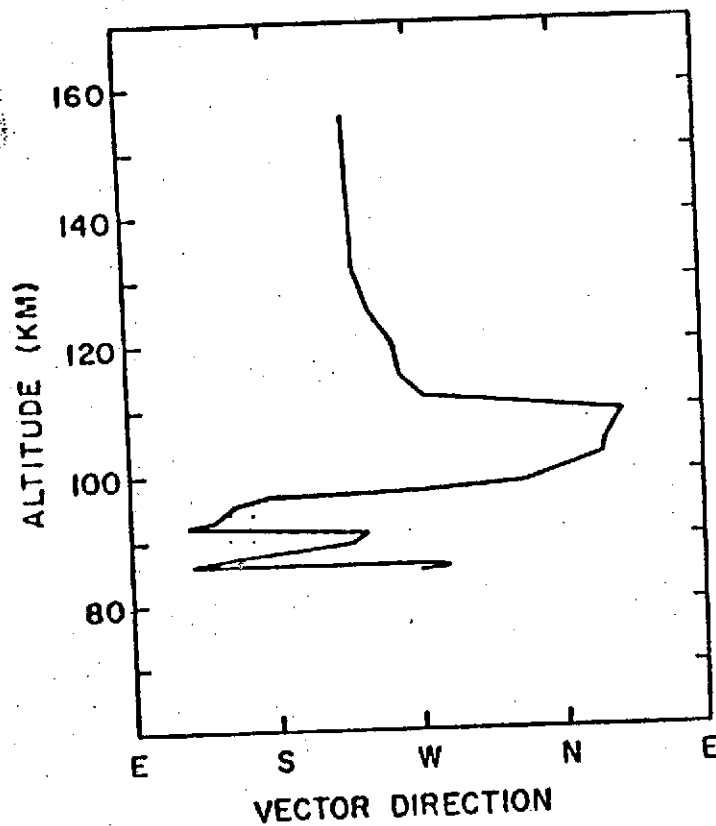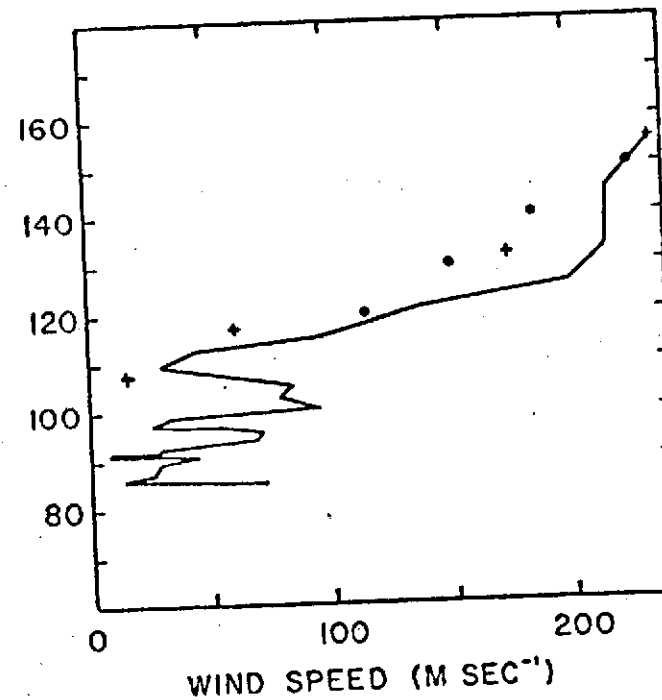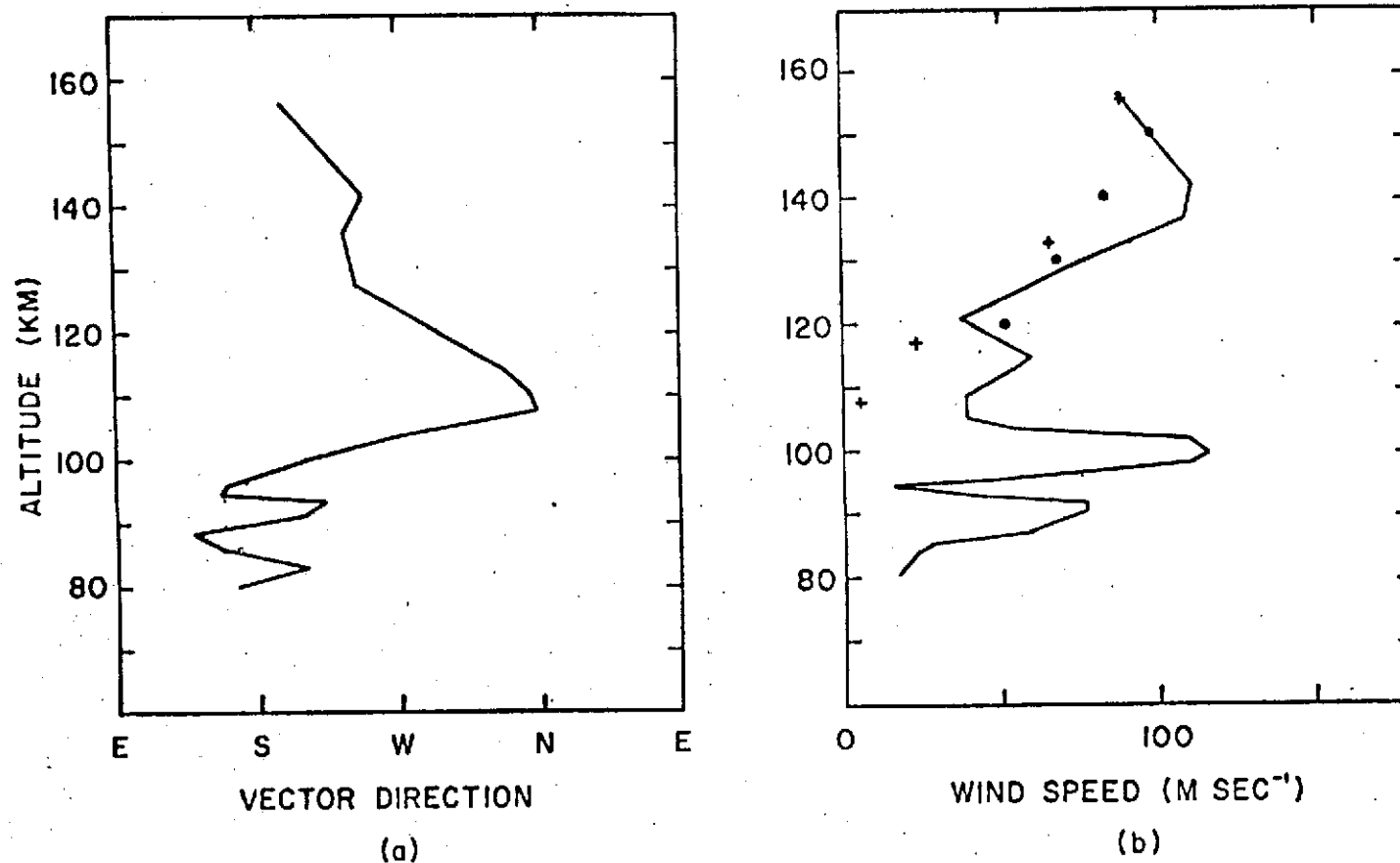## 22 MAY 1963
2203 CST

Figure 4.23   Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 2203 CST. 22 May 1963. Refer to figure   for other details.

27 FEB 1965
1740 CST

Figure 4.24 Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 1740 CST. 27 Feturary 1965. Refer to figure   for other details.

13 SEP 1966
1935 CST

Figure 4.25 Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 1935 CST. 13 September 1966. Refer to figure   for other details.
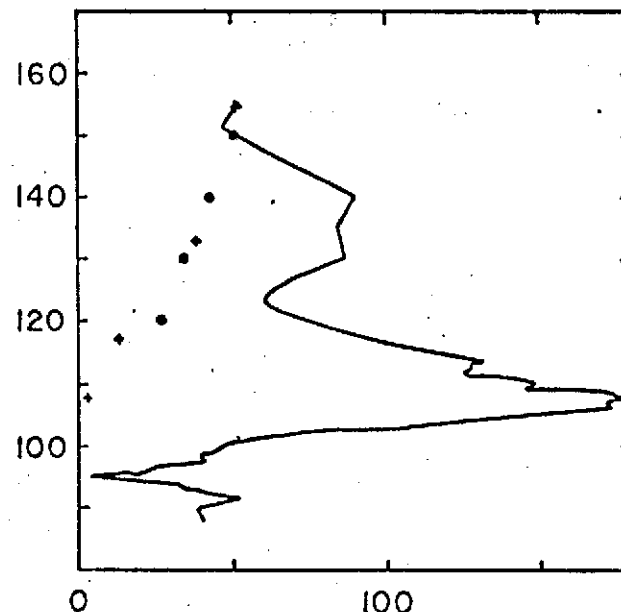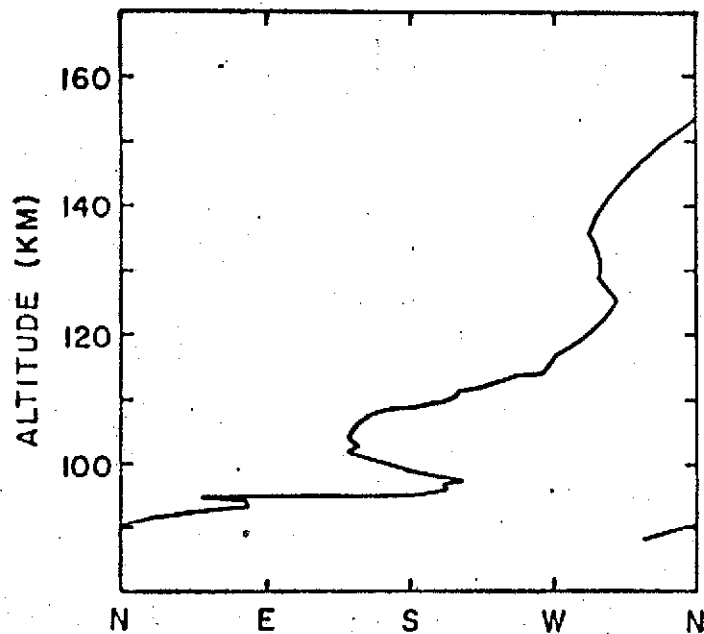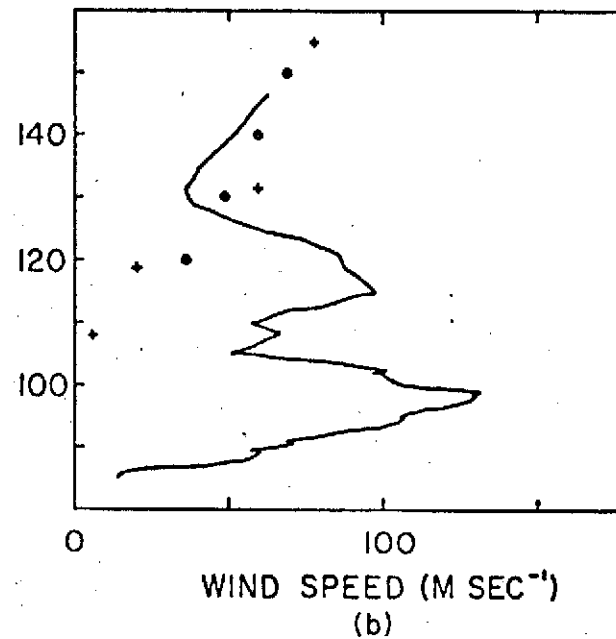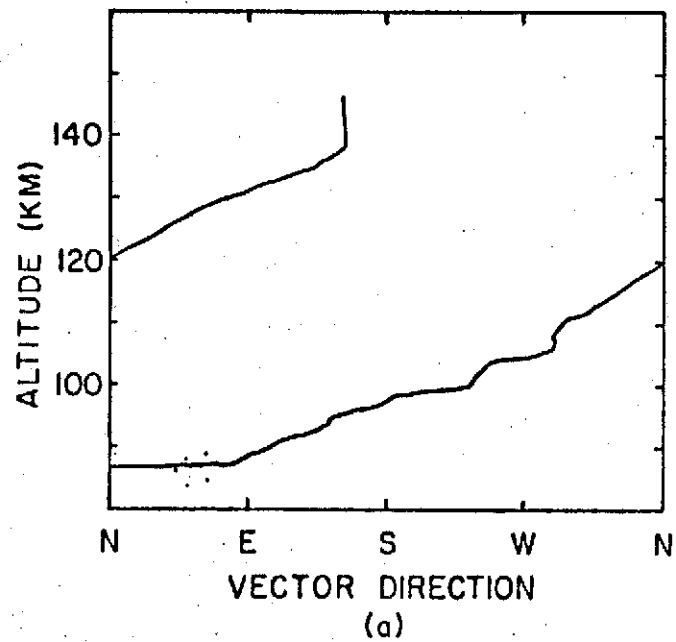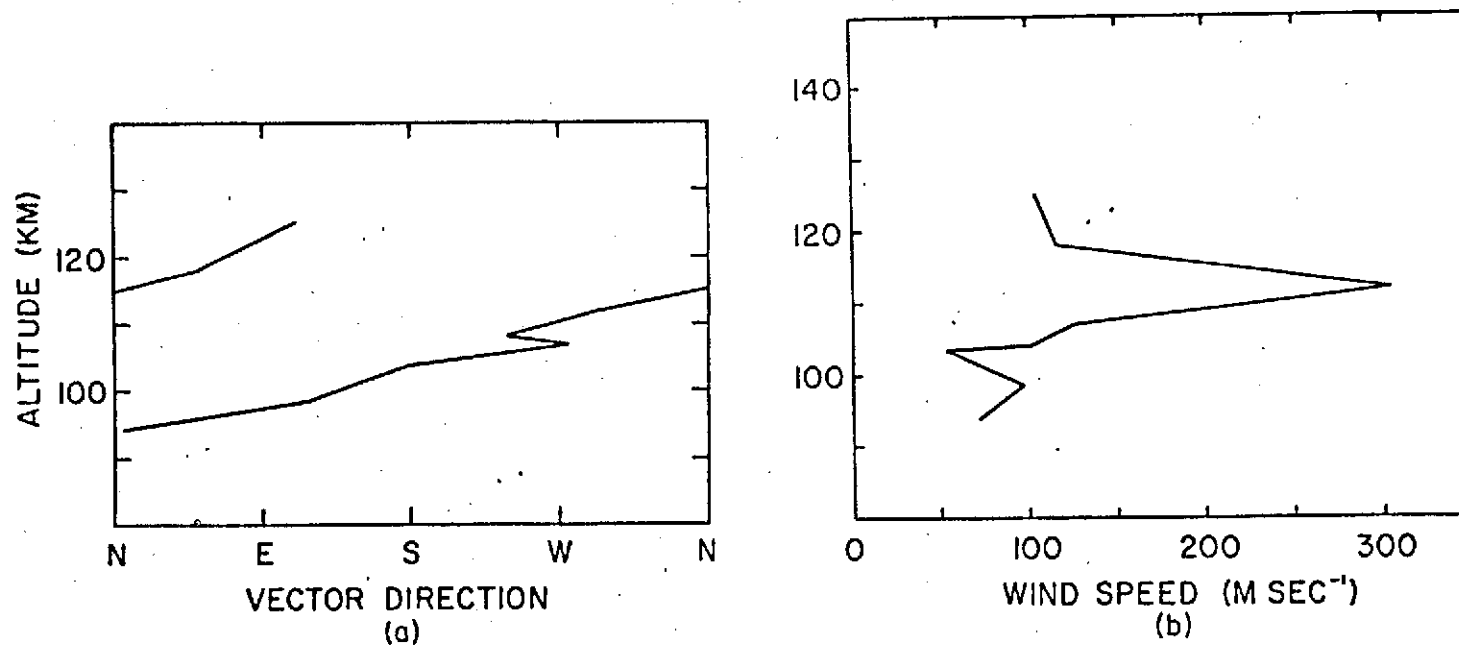
I NOV 1964
0000 CST

Figure 4.26 Vector neutral wind profile observed above Fort Churchill, Canada from a TMA release at 0000 CST. 1 November 1964. Refer to figure   for other details.

A principle feature of the data presented in figures 4.20 to 4.26 is a strong tendency for a nearly linear increase in wind speed with altitude above 120 km. This occurs in figures 4.20, 4.21 and 4.22. It is characteristic of this behavior to be associated with a marked westward direction of motion. Furthermore, each of these cases appear to coincide with a period of positive disturbance in ΔX on the Fort Churchill magnetogram. The release at 1922 LT September 15, 1966, was preceded by a positive bay of seven hours duration. During this interval the peak perturbation of ΔX on the Fort Churchill magnetometer was +120 γ. The average perturbation in ΔX over the two hours before the release was +60 γ. A small positive bay event began at 1130 LT on May 21, 1963. The ΔX component measured at Fort Churchill remained positive from this time until about one hour after the release shown in figure 4.22. A small gradually developing negative bay began about 0215 LT May 22, 1963. Thus both of the profiles shown as figures 4.21 and 4.22 were obtained at times of positive magnetic disturbances. For the two hours preceding the 2200 LT May 21 release, the average ΔX perturbation was measured to be +18 γ while this average value decreased to +9 γ for the subsequent release at 0131 LT May 22.

Figures 4.23, 4.24 and 4.25 all show significantly smaller and irregular speed profiles above 120 km. The direction profiles of these winds tend to rotate slowly with altitude and are quite unlike the profiles exhibiting a near-linear speed dependence. Very little magnetic disturbance is found on the Church-ill magnetometer for these events. The 2203 LT release on May 22 took place after three hours of no noticeable activity. Departures from the quiet-day baseline were not apparent. A longer duration of no activity proceeded the 1935 LT 13 September 1966 release (figure 4.25). The 1740 LT release of 27 February 1965 was made after 1 hour of small (10 γ) irregular oscillations. These oscillations

9

were approximately centered on the quiet day baseline so that the net deviation from quiet day during this hour is very small. This activity followed a four hour period during which $\Delta X = 0$. Thus there was very little geomagnetic activity preceding this release, and the others.

One other profile (figure 4.26) has been included for completeness. No data are given above 125 km so that this profile is of little interest in this study. It should be noted, however, that this profile is exceptional in two respects. Firstly, it is apparent that the wind vector executes more than one complete turn between 90 and 110 km. And secondly, the peak speed near 120 km is of exceptional magnitude. For a few hours preceding 00 hours local standard time on both November 1 and 2, 1964, (the release time is given ambiguously as 0000 CST 1 November 1964) the Churchill magnetogram shows no significant departure from the quiet day baseline. The spiral behavior is also apparent in figure 4.25, again at a period of low geomagnetic activity. Such spiral winds are commonly observed at middle latitudes and probably represent the influence of the semidiurnal waves.

It is obvious that there is a marked difference in the wind speed profiles obtained during periods of positive bay activity and those obtained when there was no activity at all. It is the westerly motion associated with the positive bay magnetic activity which suggests that ion drag is responsible for this motion. Furthermore, each of the three profiles showing this behavior has a northward turning of the direction profile just below 130 km, before beginning to execute the more complex motion of lower altitudes. This turning is expected from the turning of the ion motion into the Pedersen direction at low altitudes.

These profiles provide a test of the model computations of Fedder and Banks (1972) and Heaps (1972). On each wind speed profile contined in figures 4.20 through 4.25 predicted profile points have been plotted for the two models.

10

A "+" sign indicates the speed at the given height as predicted by Fedder and
Banks for a time one hour after the onset of their electric field. The dots
"." indicate profile points taken from Heaps model for 2300 hours magnetic
time, assuming that the data were taken at the center of the latitudinal electric
field distribution. The crosses (+) corresponding to Fedder and Banks model
have been normalized to the observed profile at 155 km. Heaps profile (.)
has been normalized at 150 km. It is apparent that both Heaps' model and
Fedder and Banks' model fit the observed profiles well when magnetic activity
is present. However, when activity is very low (figures 4.23 - 4.25), the
theoretical profiles are greatly different from the observed winds.

The correspondence between the theoretical and observed profiles suggests
strongly that ion drag - the driving force for these two models - is responsible
for the observed winds above 120 km when magnetic activity is present. When
there is no magnetic activity present, the observed winds are smaller and do
not behave in a manner like that predicted by the ion drag models. In these
cases, ion drag may still be an important force, but as a frictional force, not
as a driving force.

Figures 4.21 (a) and 4.22 (a) show a southerly component above 140 while
figure 4.20 (a) shows a northerly component in this same region. It is expect-
ed that this must be due to the addition of the tidal wind field to the ion
drag winds. The variation of this added component with time is consistent with
this interpretation. That is, the added component is apparently northward at
1920 local time (16 September 1966 release) and southward at 2200 and 0131 local
times (21 and 22 May 1963 releases). However there is no suitable theory for
the change of the tidal winds as a function of altitude to compare with these
observations.

11

Nevertheless, it should be expected that wind profiles obtained at times of low geomagnetic activity should be consistent with the existing tidal wind theory. The 2203 LT release of 22 May 1963 (figure 4.23) does show a southerly component above 120 km and the 1740 LT release of 27 February 1965 (figure 4.24) shows a northward meridianal component above 120 km, in agreement with the theory. However, both of these events have westward zonal components, not eastward as theory predicts. This might be due to the oscillatory perturbations present in these profiles. Additionally, a small northward electric field may be present which provides the westward zonal component without giving a measureable magnetic perturbation. With the few profiles available for study, it is not possible to come to any firm conclusions. Nevertheless, there is some correspondence between the observed profiles, both with activity present and not present, and the behavior expected on the basis of tidal wind predictions.

For the trail releases, the magnitude and direction of the ionspheric electric field, the ion drift velocity and their time histories are completely unknown. Thus it is impossible to predict neutral wind velocities on the basis of the theories available. Accordingly, the only comparison with theory which can be made is that of the height dependence of the wind vector. When this is done, normalizing to the observed wind speed at some altitude, there appears to be reasonable agreement. The spread in local time of these observations tends to rule out other forces as a cause of the observed winds. The predominance of the westward zonal component clearly justifies the ion drag interpretation. Additionally, the meridianal component seen in these releases (figures 4.21 through 4.24) is in substantial agreement with tidal wind predictions. Thus these trail data support the picture which has been developed in the discussion of the other techniques used to determine the zonal motions of the upper atmosphere.

REFERENCES

Bedinger, J.F., Compendium of Wind Data from the Vapor Trail Technique, G.C.A. Technical Report No. 66-7-N, March 1966.

Bedinger, J.F., Private communication, 1971.

Fedder, J.A. and P.M. Banks, Convection Electric Field and Polar Thermospheric Winds, JGR, 77, 2328-2340, 1972.

Heaps, M.G., Circulation in the high Latitude Thermosphere due to Electric Fields and Joule Heating, Ph.D. dissertation, Center for Research in Aeronomy, Utah State University, Logan, Utah, July 1972.

Kockanski, A., Atmospheric Motions from Sodium Cloud Drifts at Four Locations, Mon. Weather Rev., 94, 199-212, 1966.